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IMPEDANCE OF MONOPOLE ANTENNAS ON VEHICLES BY MOMENT METHODS.(U)
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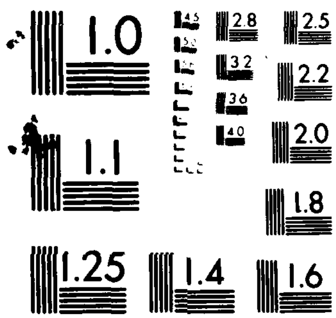

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ROYAL SIGNALS AND RADAR ESTABLISHMENT

Memorandum 3414

IMPEDANCE OF MONOPOLE ANTENNAS ON VEHICLES BY MOMENT METHODS

D. J. Brammer

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SUMMARY

The moment method program NEC-1 was used to investigate the accuracy with which antenna impedance can be calculated by moment methods for monopole antennas on conducting vehicles. Both wiregrid and surface patch methods were used. It is shown that providing certain constraints are adhered to, reasonably accurate results are possible for antennas that are not too thick.

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RSRE MEMORANDUM No. 3414

IMPEDANCE OF MONOPOLE ANTENNAS ON VEHICLES BY MOMENT METHODS

D J Brammer

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1 INTRODUCTION

Moment method programs have been widely used to provide accurate polar diagram information. Antenna impedance calculations have until recently not been so accurate except perhaps in the isolated dipole case. The program NEC-1 [1] has an improved current continuity algorithm and may be used to calculate impedances. To test the impedance calculations an idealised shape was used for which theoretical and experimental data was available in the literature [2]. Measurements were also performed on a copper model using a network analyser.

2 IDEALISED MODEL DESCRIPTION

Figure 1 shows the idealised shape which is a hemispherical boss on a perfectly conducting ground plane. Measurements and theoretical results for this are available in the paper by Tesche and Neureuther [2] and may be used to check results obtained by moment methods. The results in [2] are obtained by a moment type method but the Greens function for the conducting sphere is used i.e. only the current on the wire is expanded. The field at another point on the wire due to the current on the wire is obtained from a series expansion of the classical Greens function for the conducting sphere. An alternative idealised model to consider was a monopole over a round flat plate. This alternative was not chosen since the magnetic field boundary condition patch method incorporated in NEC-1 cannot be used for thin metal plates, also standard results available for this case were not thought to be as accurate as those for the hemispherical model. The need to connect the antenna to the network analyser for experimental checking was facilitated by using a hemispherical boss on a ground plane rather than an isolated sphere and monopole. The model is a 25.4 mm radius hemispherical boss with a 50.8 mm long monopole on top. The frequency range of interest is the resonant and anti resonant frequency of the two inch monopole i.e. approximately 1.5-4 GHz. The radius of the monopole in reference [2] is ambiguous and so radii of .44 mm and .89 mm were both considered. The thickness parameter $\Omega = 2 \log_e (2h/a)$ where h is the height and a the radius equals 10.8 and 9.5 respectively for monopoles of these radii.

3 WIREGRID AND SURFACE PATCH MODELLING USING THE NEC-1 PROGRAM

The wiregrid model is shown in figure 2. Since the frequency range of interest is 1.5 -4.0 GHz the wavelength varies from about 20 cm down to 7.5 cm. Each element of the grid should be less than an eighth of a wavelength or 9.4 mm. The antenna is placed on an equator rather than a pole so that the antenna is joined to a normal square mesh rather than a multiwire junction. The radius of the wires used to represent the surface is such that the total surface area of the wires is either 2 or 4 times the surface area being modelled [3]. This means that for a square mesh the radius of a wire element equals length/2π or length/π.

Instead of representing the current flowing on the surface by the current flowing in the wires of a mesh as shown in figure 2 it is possible to represent this current as flowing on the surface in two orthogonal directions on square flat patches arranged to make up the hemisphere being modelled. This is shown in figures 3 and 4. The area of each patch is approximately the same as a wiregrid mesh. Each patch subtends at the centre of the sphere an approximately equal solid angle. The program NEC divides any patch with a wire connected to its centre into 4 and so there is some point in making the patch under the antenna somewhat larger. In order to check the effect on impedance of the size of this patch and ensure self consistency in the moment method solution, the second representation shown in figure 4 has a smaller patch under the antenna nearer to the size of other patches. The shape of each patch is shown as square, but the program only takes note of the total surface area of each patch and the orientation of its surface.

4 NETWORK ANALYSER EXPERIMENTS

A 50 ohm sub miniature socket was flush mounted at the top of the hemisphere. Two antennas of thicknesses 0.44 mm and 0.89 mm could be plugged into the socket as could a shorting plug. Using an automatic network analyser the reflection coefficient amplitude and phase were measured, referred at the end of the 50 ohm line, i.e. at the top of the socket, by measuring first with the antenna and then with the shorting plug in position.

5. RESULTS AND COMPARISONS

The impedance measurements from reference [2] are replotted in figure 5. The quantities plotted are the theoretical impedance at the driving point between the monopole and the sphere and the measured values at the end of a coaxial line referred to the connection at the antenna base. The book by King [4] suggests that the actual measured value referred to the end of the line will differ from the idealised theoretical value by a fixed negative capacitance due to end effects at the line junction with the antenna. Tesche and Neureuther quote a value of -0.076 pF for their particular coaxial line dimensions. The theoretical values have this added before being plotted in their paper. This -.076 pF was determined by measuring the same monopole over a plane metal ground. The capacity required is that which adjusts the resonant frequency of this experimental monopole to known theoretical results for a monopole in one of their references.

Impedances from wire grid modelling are shown in figure 6 for the 0.44 mm case. The results do not depend too much on the diameter of the wires used to represent the surface of the hemisphere, doubling the wire radius from the 2 times surface area equivalent to the 4 times would only just be noticed in

figure 6, the effect is of the order of the thickness of the plotted line. Dividing the monopole into either 7 or 12 elements alters the feed element length to either 1/7 or 1/12 of the monopole height. This does have an effect which can be seen in figure 6. Also shown is the experimental measurement made using the network analyser. This result agrees quite closely with the Tesche and Neureuther experimental result in figure 5.

Figure 7 shows experimental and NEC 1 results for the thicker monopole of .89 mm radius (thickness parameter 9.5). Also shown is the NEC-1 result loaded with .08 pF capacitance which then agrees very well with the measured result. The results in figure 6 really only differ by a fixed capacitance, this can be explained by reference to figure 8. The solid curves are taken from reference [5] and show the imaginary part of the admittance, the susceptance, of a half wave monopole of radius a over a conducting half plane fed by a coaxial feed. The outer of the coaxial feed is of radius b the inner radius a. The gap between the monopole and the ground is therefore b-a. The susceptance is plotted as a function of b/a for three values of the thickness parameter 9.3, 10.69 and 12.9. The dashed curves correspond to the actual thickness parameters of the monopole on the hemisphere i.e. 9.5 and 10.9. As the ratio b/a tends to unity the susceptance eventually diverges. This is said by reference [5] to be due to the capacitance of the circular knife edge. The straight part of the plots may be extrapolated back to b/a = 1 to give idealised values. Tables of theoretical values in [5] have been adjusted with a capacitance to conform to measured values obtained via this extrapolation. Also plotted in figure 8 are the corresponding results for the equivalent full wave dipole calculated by NEC-1. The abcissa is now (b-a)/a where b is now the feed element length. These results behave in a similar manner having the same straight line region and diverging as the feed element length tends to zero. The reason why the susceptance diverges for the wire integral equation is suggested in [6] on page 13 as failure to use the exact integral equation kernel, on page 114 as inaccuracies of the thin wire approximation and on page 158 as due to the gap susceptance.

Althougn figure 8 is strictly for a half wave monopole over a plane earth, the change in susceptance is thought to be an effect localised near the feed region. Also plotted on figure 8 therefore are the wiregrid, surface patch and Tesche and Neureuther results for the thinner (Ω = 10.9) monopole on a sphere. The results have been plotted on a false zero to allow for any absolute difference due to the plane or curved region below the monopole. These results are consistant with the Tesche and Neureuther theoretical result having a small effective gap but without the knife edge capacitance. The wiregrid and surface patch results to a reasonable degree of approximation lie on the lower dashed line with Ω = 10.9. Because so many elements or patches are used to model the hemisphere it is not possible to obtain a small value of b/a without using a prohibitively large total number of elements. The best approach would seem to be to use figure 8 to extrapolate the susceptance to a lower value of b/a. Take for example the .89 mm radius monopole in figure 7 with thickness parameter 9.5. The b/a for the 7 element monopole wiregrid model is 8.2, for the experimental arrangement b = 2 mm giving b/a = 2/1.4 = 1.4. Figure 8 suggests a susceptance of about 1.8 mmho should be added (corresponding to a capacitance (half wave monopole) of .097 pF) to bring the NEC-1 values to the experimental. Figure 7 shows a value of .08 pF is required.

The effective value of b/a appears to be about twice the value estimated from the dimensions of the experimental setup. A similar situation occurs with the thinner antenna, the measured point is in this case shown in figure 8 as a

sloping cross. Although it is plotted with a b/a of 3.4 a value of twice this is more appropriate. This may be due to the fact that the socket has a dielectric plug (thus increasing the effective value of b) to support the inner conductor whereas figure 8 refers to air spacing.

The surface patch impedance results are shown in figures 9 and 10. Figure 9 shows that provided the number of elements in the monopole is kept the same, the effect of the size of the patch is small although the results for the larger patch appear better. Figure 10 shows the effect of changing the size of elements in the monopole from 1/4 the patch diagonal to equality with the patch diagonal for the thin monopole ($\Omega = 10.9$) case. This effectively quadruples the b/a ratio making an appreciable difference to the susceptance. These three points lie quite well on the appropriate line in figure 8. The results when the feed element is 1/4 the patch diagonal is not as accurate as the others for the reactance around resonance.

6 CONCLUSIONS

Provided certain guidelines are adhered to reasonable values for impedance may be determined by using the program NEC-1. These are:-

1. Avoid large changes in dimension between element length in the monopole and element length or patch size in the surface being modelled. For the patch case an element length of around the patch semi-diagonal appears best.

2. Note the b/a for the wiregrid or surface patch model and determine the additional capacitance to be added to obtain the idealised impedance or any measurements with their own effective value of b/a. Note that the effective value of b/a appears about twice the actual value, at least for a base with a dielectric plug supporting the central conductor.

3. In the practical case when the exact layout of dielectric and conductors in an antenna base may be uncertain it is adviseable to find the value of capacitance required to adjust impedances to their idealised values, for example by noting the antiresonant frequency over a plane earth. Alternatively a few spot measurements may be used to determine the capacity required to adjust wiregrid or surface patch measurements to measured values. Once this has been done for a particular antenna base, this value of the capacitance should be valid for all other enviroments of the antenna base. If this is thought to be unsatisfactory note even standard theoretical values obtained with the King Middleton second order interation method have been adjusted in [5] to confirm to experimental values.

7 ACKNOWLEDGEMENT

Thank are due to Mr G W Parkes, L4 Division, for making the experimental measurements.

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1 G J Burke and A J Poggio: "Numerical Electromagnetic Code (NEC-1) parts I, II, III", Lawrence Livermore Laboratory, Calibfornia, USA (1977).

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5 R W P King: "Tables of Antenna Characteristics", IFI/Plenum, New York (1971).

6 R Mittra, Editor: "Numerical and Asymptotic Techniques in Electromagnetics", Springer Verlag (1975).

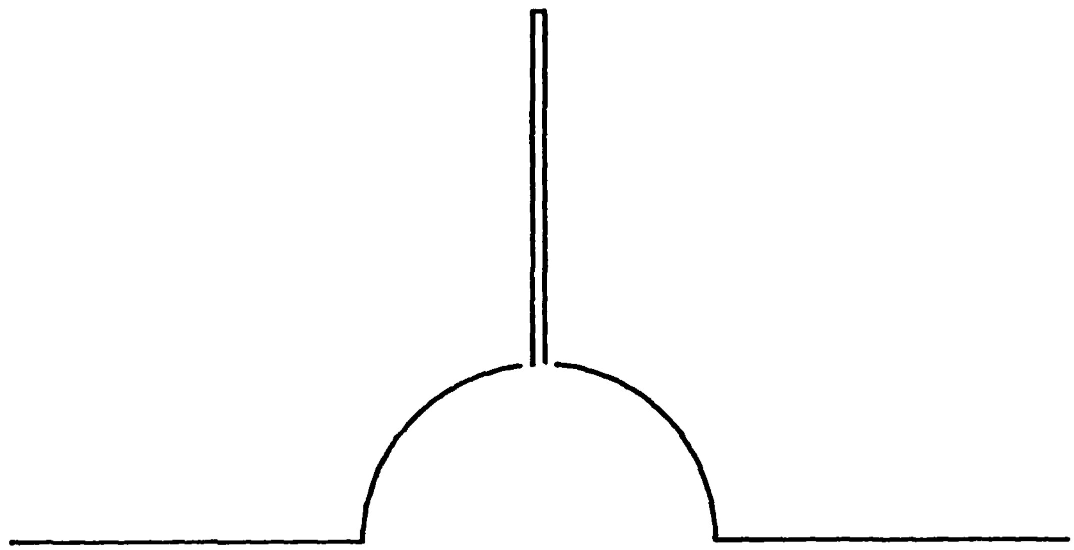

Figure 1 Idealised hemispherical conducting boss on conducting ground plane

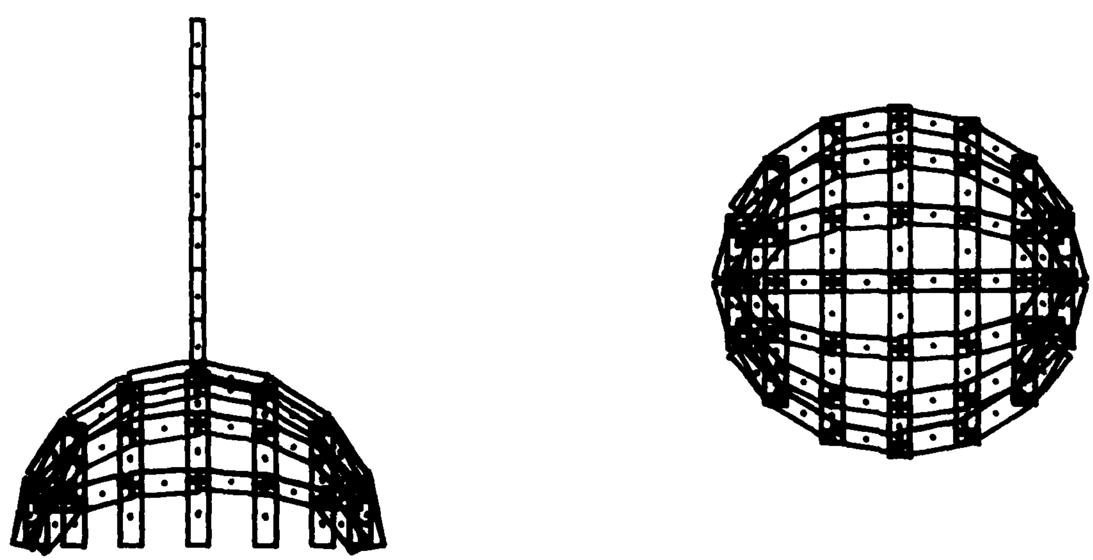

Figure 2 Wiregrid representation

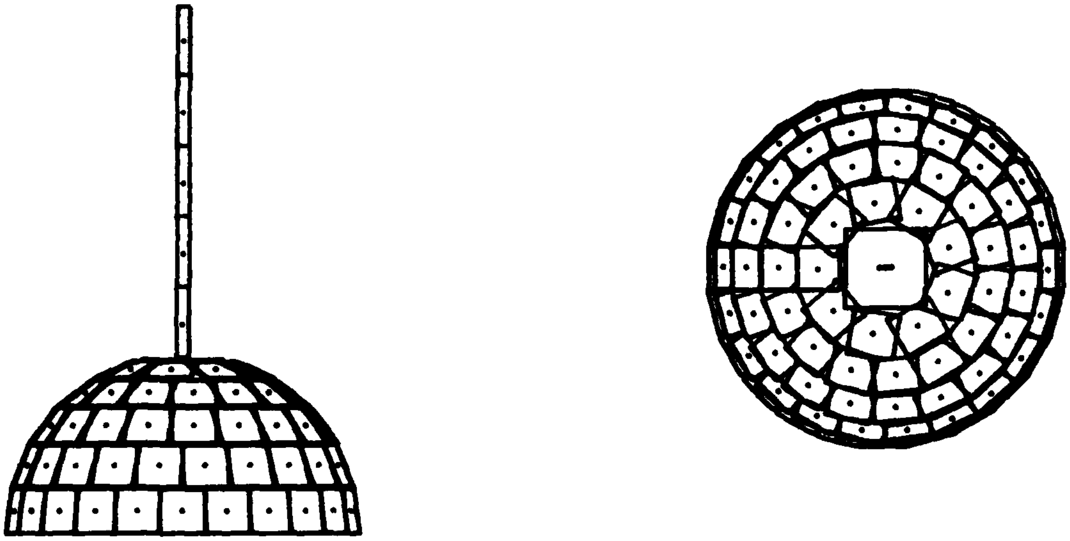

Figure 3 Patch representation with large patch under antenna

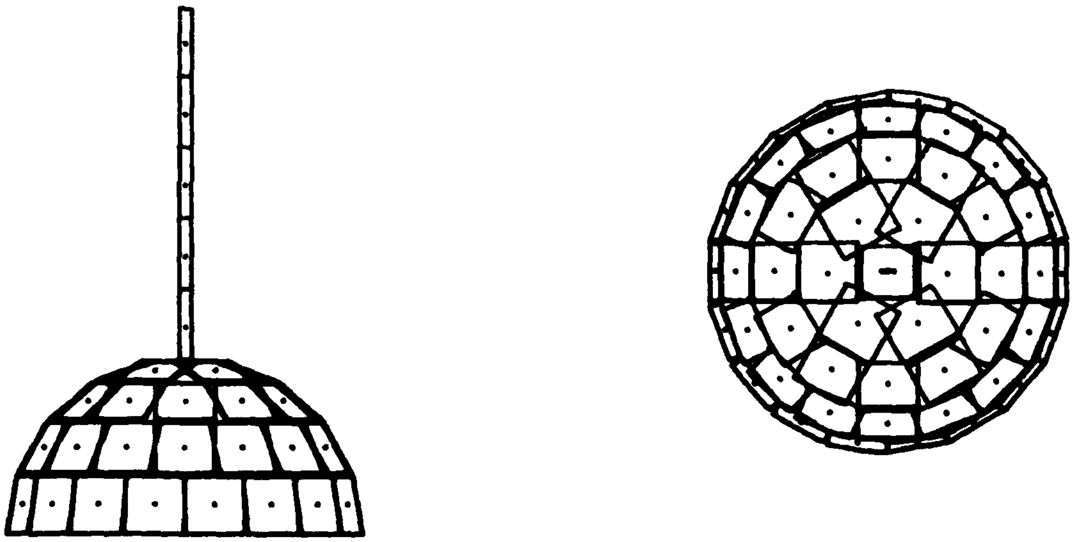

Figure 4 Patch representation with small patch under antenna

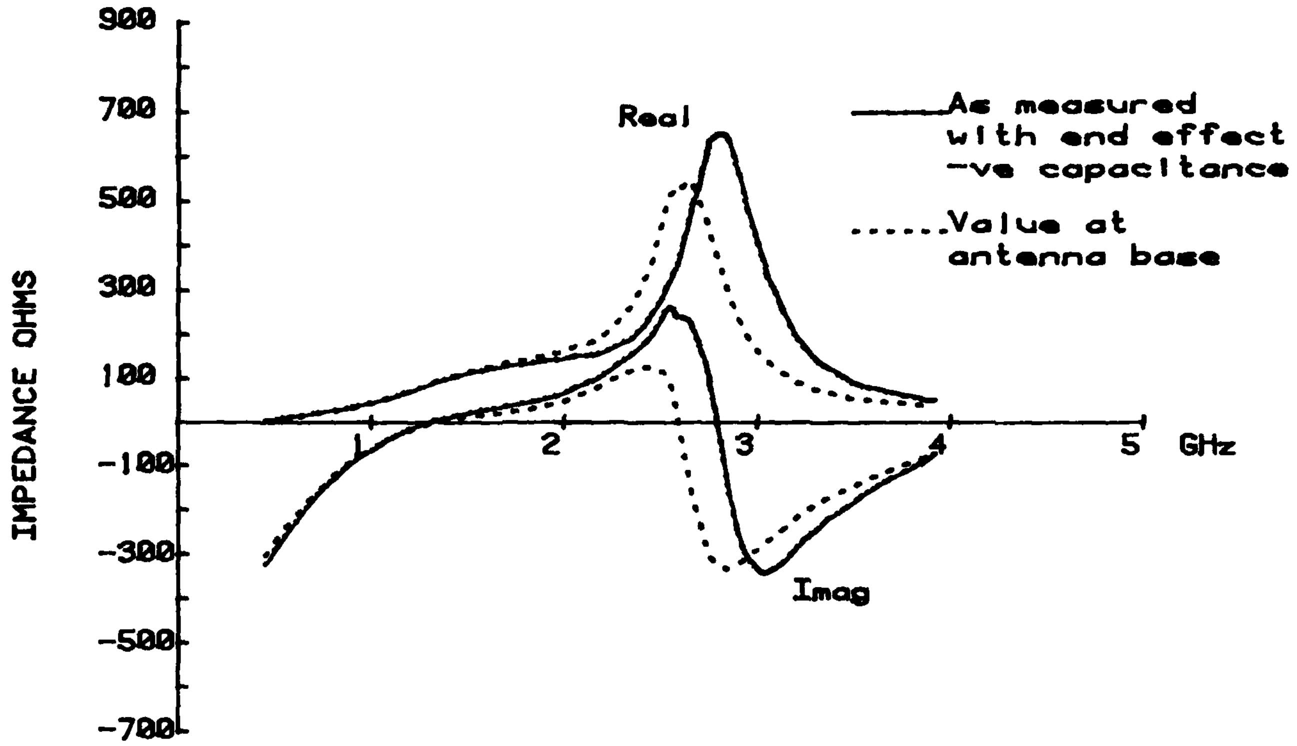

Figure 5 Impedance from paper by Tesche and Neureuther with and without negative end effects capacitance.

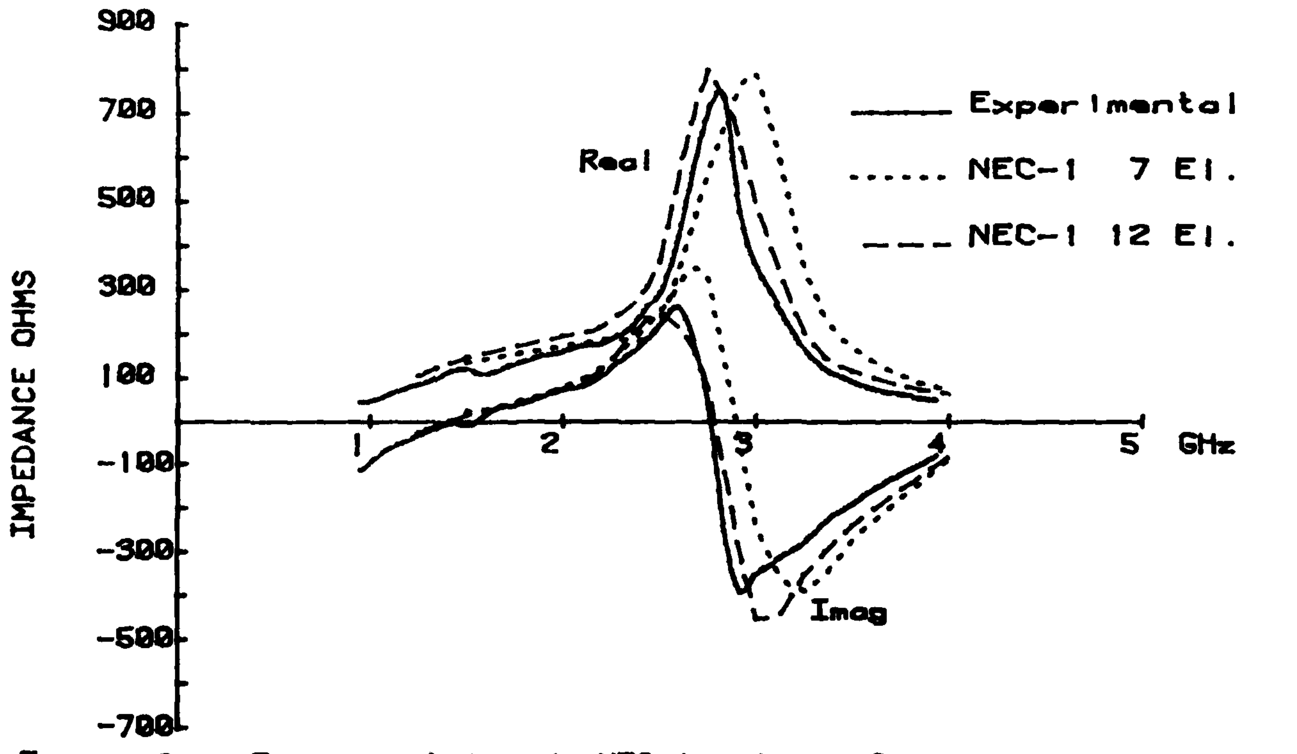

Figure 6 Experimental and NEC-1 values of impedance for 0.44 mm radius monopole which is divided into 7 and 12 elements respectively.

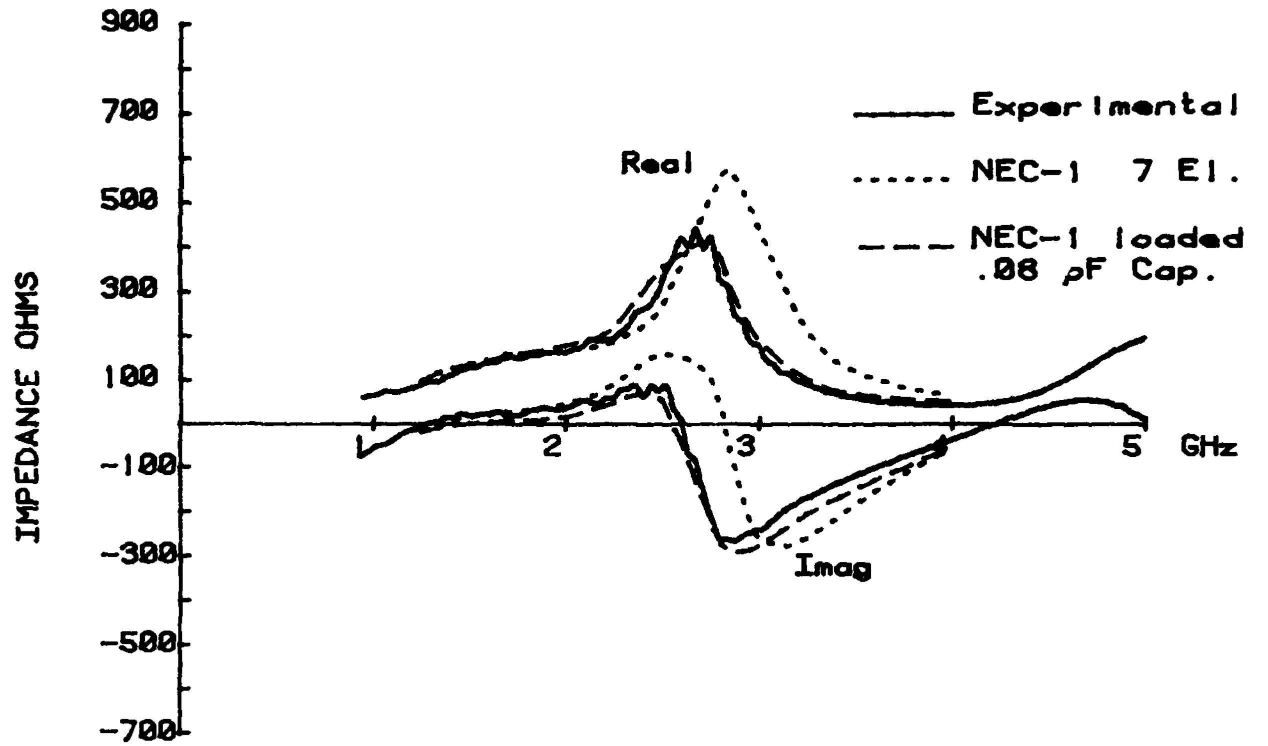

Figure 7 Experimental and NEC-1 values of impedance for 0.89 mm radius monopole. Also shown NEC results loaded with +0.08 pF capacity

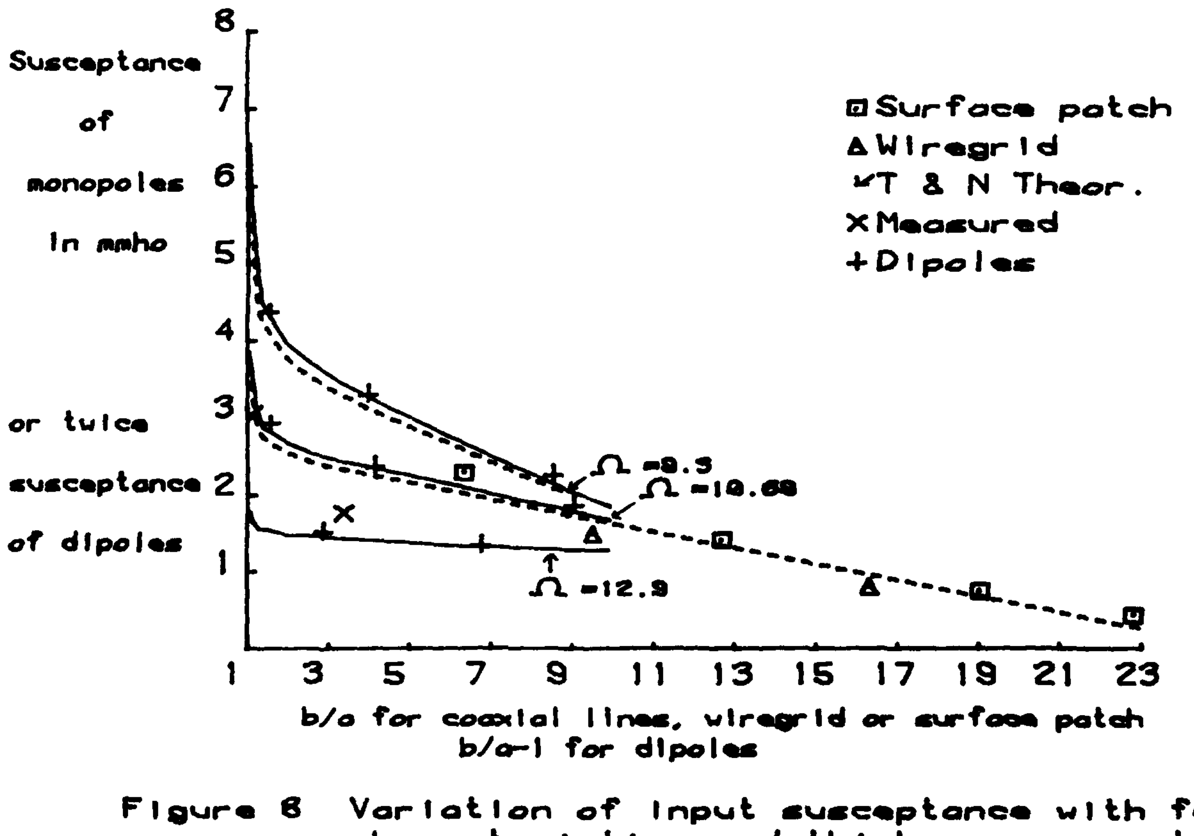

Figure 8 Variation of input susceptance with feed characteristics and thickness parameter

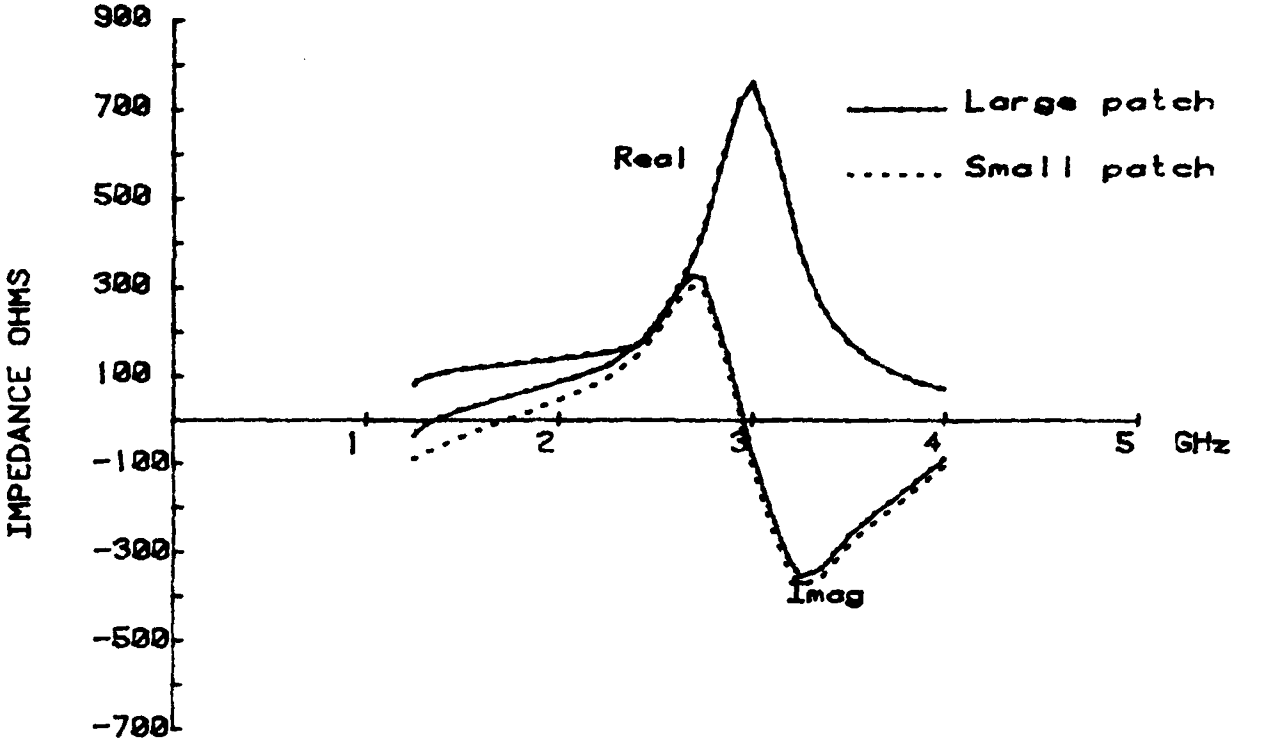

Figure 9 Surface patch impedances with monopole divided into 6 elements. Large and small patches under antenna.

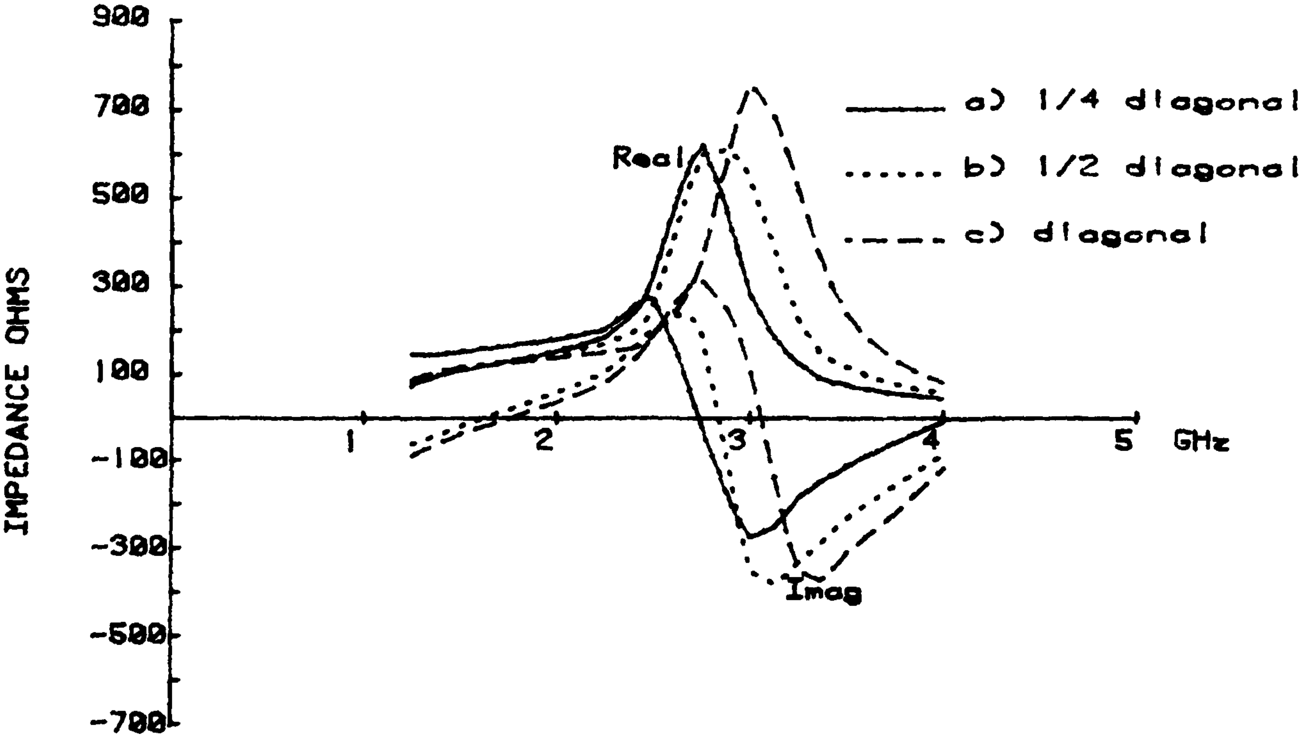

Figure 10 Surface patch impedances with length of bottom element equal to a) 1/4 patch diagonal b) 1/2 patch diagonal c) The patch diagonal

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